

Background

Body size determines rates of respiration and production, energy requirements, mortality rates, patterns of predation and vulnerability to mortality^{1,3}. Since many species grow in mass by 5 or more orders of magnitude during their life cycle, and since cannibalism, cross-predation and transient predator-prey relationships are common, there are compelling reasons to adopt size rather than species-based analyses of marine food webs³. If clear relationships can be established between body size distributions and food web structure, these may provide a basis for integrating community analyses based on food webs and life histories, and for examining relationships between food-web structure and species richness^{4,7}.

Cross-species relationships between body size and trophic level

We investigated relationships between the body sizes of north-east Atlantic fishes and their trophic level. We used the abundance of the heavier stable isotope of nitrogen ($\delta^{15}\text{N}$) in white muscle as an index of trophic level. Cross-species analyses demonstrated that body size was not significantly related to trophic level (Figure 1), even though many individual species fed at higher trophic levels with increasing body size (Figure 2). The absence of a significant cross species relationship was supported by a comparative analysis of the same data^{7,8}. From our results, we conclude that fish have evolved to feed at many trophic levels, independent of body size.

Body-size and trophic level in fish communities

The results of the cross-species analyses between body size and trophic level contrasted with patterns in the size and trophic structure of entire fish communities. When fish communities were divided into body mass classes, there were strong positive relationships between body mass and trophic level (Figure 3). Our results show that body size does not provide a useful surrogate of trophic level for individual species, but that body size is an excellent predictor of the mean trophic level of the community. Within the community, small species are only abundant when they feed at low trophic levels and larger species are only abundant when they feed at higher trophic levels. Thus the passage of energy through the food web is strongly constrained by body size¹⁰.

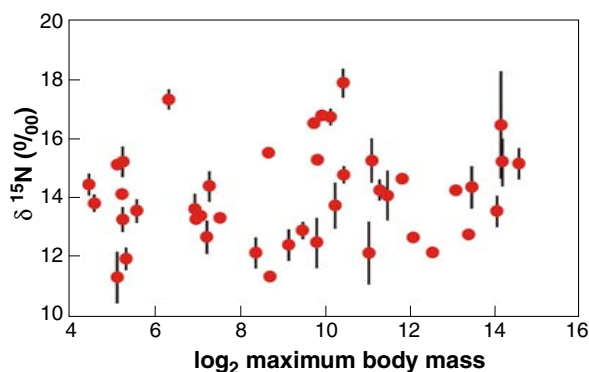


Figure 1: Relationships between the $\delta^{15}\text{N}$ of white muscle tissue (mean \pm 95% CL) and maximum weight of North Sea fishes. Since $\delta^{15}\text{N}$ (trophic level) increases with body size within species, fish from different species were compared at an equivalent stage of their life history. The relationship between maximum weight and $\delta^{15}\text{N}$ was not significant ($F_{1,41} = 1.16$ $p > 0.1$), and this result was confirmed with a phylogenetic comparative analysis^{7,8}.

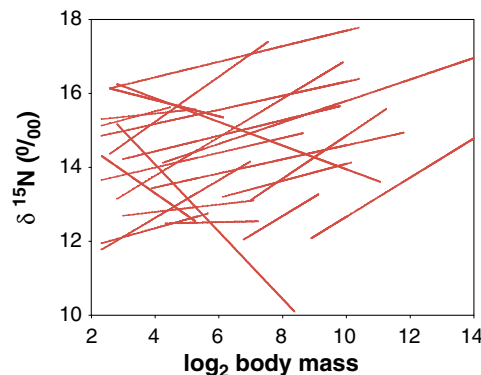


Figure 2: Fitted relationships (from linear regression) between body mass and $\delta^{15}\text{N}$ for species of North Sea fishes. The size ranges for each species are set from the mass of the smallest individual sampled to the largest recorded body mass. These species account for >98% of the total biomass of all species recorded in trawl net surveys.

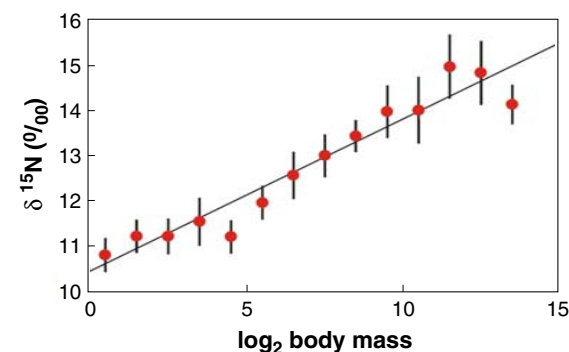


Figure 3: Relationship between the $\delta^{15}\text{N}$ of white muscle tissue and body mass class for the North Sea fish community. The relationship is highly significant ($\delta^{15}\text{N} = 0.335 \log_2 \text{body mass} + 10.4$; $r^2 = 0.93$; $F_{1,12} = 147.8$; $p < 0.0001$). The slope of the relationship implies a mean predator-prey body mass ratio of 496:1 (mass ratio = $2^{3.45 \log_2}$, assuming a $\delta^{15}\text{N}$ fractionation of 3.4‰ per trophic level⁹).

References

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Next steps

In future, we will explore links between the trophic structure of these size-based food webs and the species richness and body size distributions of component species. The application of terrestrial theory to these marine ecosystems may present a significant challenge as, in most species, growth is indeterminate and growth in body mass may exceed 5 orders of magnitude!

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